

**NCSX
Specification**

TF Coil Conductor Specification

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Record of Revisions

Revision	Date	Description of Changes
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1 SCOPE

The National Compact Stellarator Experiment (NCSX) is an experimental research facility that is to be constructed at the Department of Energy's Princeton Plasma Physics Laboratory (PPPL). Its mission is to acquire the physics knowledge needed to evaluate compact stellarators as a fusion concept, and to advance the understanding of three-dimensional plasma physics for fusion and basic science.

The TF Coils are a Primary component of the NCSX Device. Eighteen equally spaced D shaped coils surround the core of the machine. Each of these 12 turn coils is wound using a solid copper conductor with an extruded center hole for liquid nitrogen cooling. This specification establishes the manufacturing and acceptance requirements for the copper conductor that will be used in the fabrication of the TF Coils. It defines the alloy, form, quantity and integrity of the hollow extruded copper conductor. To minimize the risk of coil failure, strict adherence to these specifications is essential.

2 APPLICABLE DOCUMENTS

SE131-014 TF Coil Conductor Detail

ASTM B187-03 Standard Specification for Copper, Bus Bar, Rod, and Shapes

ASTM B193-02 Standard Test Method for Resistivity of Electrical Conductor Materials

ASTM E8 Standard Test Methods for Tension Testing of Metallic Materials

ASTM E18 Standard Test Methods for Rockwell Hardness of Metallic Materials

3 REQUIREMENTS

3.1 Item Definition

The item is a continuous length of extruded copper conductor with a center hole wound into a pancake spool.

3.2 Design and Construction

3.2.1 Conductor Geometry

3.2.1.1 Conductor Height and Width

The conductor height and width shall conform to the TF Coil Conductor Detail SE131-014

3.2.1.2 Conductor Length

Each individual spool shall be wound in a continuous length with no splices. The conductor shall be a minimum of 100 ft long and a maximum of 110 ft long.

3.2.1.3 Conductor Hole

The conductor shall be extruded with a continuous .312 inch +/-0.005 inch diameter hole centered on the conductor cross section within the tolerances specified in TF Coil Conductor Detail SE131-014

3.2.2 Conductor Characteristics

All specified material properties are at room temperature

3.2.2.1 Copper Grade

The copper shall conform to ASTM B187 UNS#C10700 except that the copper is cold drawn to produce the required yield strength, tensile strength, and hardness specified in paragraphs 3.2.2.2, 3.2.2.3, and 3.2.2.4.

3.2.2.2 Yield Strength

Yield Strength shall be 26,000 psi min. to 30,000 psi max. (0.5% extension under load) at room temperature

3.2.2.3 Tensile Strength

Ultimate Tensile Strength shall be 36,000 psi minimum with a minimum extension under load of 25% at room temperature

3.2.2.4 Hardness

The conductor shall have a Rockwell Hardness F between 60 and 70 at room temperature. If there is a discrepancy between the Hardness requirement and the Yield Strength requirement the Yield Strength measurement shall be the governing requirement.

3.2.2.5 Conductor Resistance

The conductor resistance shall be not more than 13.2 micro ohms per foot of conductor at room temperature.

3.2.2.6 Conductor Integrity

The hole profile shall show neither re-entrant material or notches greater than 0.020 inch. Cracks, laps, fold, scale and any other discontinuity longer than 0.020 inch normal to the hole surface, shall not be visible when inspected at 100x magnification.

3.2.3 Standards of Manufacture

3.2.3.1 Cleanliness

The Subcontractor shall ensure that the finished conductor has been thoroughly cleaned with a solvent adequate for the removal of any trace amounts of lubricants that may have been used both on the outer surface and in the hole of the extrusion. The Subcontractor shall take the necessary precautions to ensure that the finished conductor is clean, free of any oils, or dirt related to processing or handling.

3.2.3.2 Best Practice Requirements

The finished material shall be free from blisters, slivers, laps, seams, cracks and scale, as well as from all other imperfections, such as damaged corners or edges, not consistent with best commercial practice

4 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Inspection

The responsibility for performing all tests and verifications rests with the supplier. PPPL reserves the right to witness or separately perform all tests specified or otherwise inspect any or all tests and inspections. Methods used for inspection shall be proposed by Subcontractor and approved by PPPL

4.2 Quality Conformance Inspections

This section provides the conformance and inspection requirements for the items specified in Sections 3 and 5.

4.2.1 Verification of Conductor Geometry / Dimensions

4.2.1.1 Conductor Height and Width

The conductor width and height shall be measured to verify compliance with Sections 3.2.1.1. Six measurements shall be taken at the start of the conductor length, in the middle of the conductor length, and at the end of the conductor length. The six measurements at each of these locations shall be six inches apart. Measurements at the start and end of the conductor shall be at least 12 inches from terminus of the conductor. All measured values shall be recorded.

4.2.1.2 Conductor Length

The Subcontractor shall perform an in-process measurement of the conductor length to verify compliance with Section 3.2.1.2. The length of each spool is to be reported to PPPL to within a tolerance of +/- 2 inches.

4.2.1.3 Conductor Hole

The ends of each conductor shall be checked to verify that the diameter of the cooling hole and the centering of the cooling hole is within the required tolerance as specified in paragraph 3.2.1.3. A ball is to be passed through the finished length of conductor to check for any imperfections in the length of the spool. The ball shall be no less than .250 inches in diameter.

4.2.2 Verification of Copper Grade

Material certifications showing actual chemical, mechanical, and electrical properties of the conductor shall be provided to verify compliance with Section 3.2.2.1.

4.2.3 Verification of Material Properties / Testing

All testing shall be performed at room temperature

4.2.3.1 Test Specimens

A minimum of 10% of the spools shall be selected to provide samples for testing i.e. for 77 spools eight sets of test samples are required. In addition there must be at least two sets of samples from a group of spools that came from any unique lot of billets. If there are fewer than twenty spools that were manufactured from a particular lot of material there must still be a minimum of two sets of test samples from that group of spools. A "set of test samples" refers to the group of test pieces required to provide the yield, tensile, and hardness testing. Test Specimens must be marked or identified in such a manner that the origin of each sample can be traced back to a particular spool. Test samples to be shipped to PPPL with the conductor.

4.2.3.2 Yield Testing

Specimens are to be tested to verify yield strength specified in section 3.2.2.2 per test methods in ASTM E8

4.2.3.3 Tensile Testing

Specimens are to be tested to verify tensile strength in section 3.2.2.23.2.2.3 per test methods in ASTM E8

4.2.3.4 Hardness Testing

A) The conductor shall be tested along its length every 10 ft to verify the hardness specified in section 3.2.2.4 using the ball tip test methods in ASTM E18. Test point locations are to be marked using a felt tip marker.

B) The test specimens used to test for yield and tensile strength shall be tested for hardness prior to being pulled so that a correlation between hardness and yield can be documented.

4.2.3.5 Resistance Testing

A resistance measurement shall be made to verify compliance with Section 3.2.2.5 per ASTM B193-02. The test method is to be reviewed and approved by PPPL prior to testing.

4.2.4 Conductor Integrity

Each conductor test specimen (see paragraph 4.2.3.1) shall be examined at 100X magnification for compliance with paragraph 3.2.2.6. Each spool of conductor is to be pressure tested with a method prescribed by the vendor and approved by PPPL

4.2.5 Cleanliness

The subcontractor shall provide certification, either separately or as part of other documentation, that the conductor has been cleaned in accordance with 3.2.3.1

4.2.6 General Inspection

Each spool is to be inspected and the inspection documented before shipment to verify the final condition of the finished product meets the requirements stated in paragraph 3.2.3.2.

5 PREPARATION FOR DELIVERY

5.1 Conductor Spooling

The conductor will be wound with the wide side (.966 inch) of the conductor lying flat. The spool will be wound against the narrow .709 dimension bending the coil the “hard way” into a single pancake layer. The inner diameter of the spool will be of a diameter between 36” and 38”. There will be only one continuous length of conductor per spool. The spools shall be independently restrained with non metallic bands or by other means so that when removed from the crate they can be handled without unwinding.

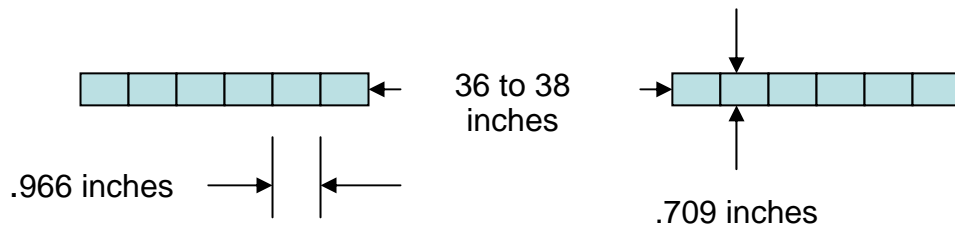


Figure 1 - Conductor and spool layout (not to scale, figure only imparts orientation of conductor)

5.2 Conductor Weight

Each spool of conductor shall be weighed to determine the raw weight of the conductor. (Ref: The weight of the conductor is 235.3 lbs per 100 feet)

5.3 Conductor Protection

Each spool of conductor will be plastic wrapped to protect the conductor from dirt and foreign materials.

5.4 Crating

The spools shall be crated to protect the conductor from shock and weather conditions, including precipitation. The crate shall be built for handling with slings from overhead cranes, and transport by forklifts. Container to be approved by PPPL before shipping.

5.5 Verification of Preparation for Shipping

The Subcontractor shall verify compliance with the requirements for conductor spooling (Section 5.1), conductor protection (Section 5.2), and crating (Section 5.4)